

# PATENT SPECIFICATION

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## (54) VEHICLE WHEEL SPEED SENSOR

(71) We, WAGNER ELECTRIC CORPORATION, a corporation of the State of Delaware, having its offices at 1 Summer Avenue, Newark, New Jersey 07104, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to vehicle wheel speed sensors and in particular to those for use in brake antilock systems.

In the past, there have been various types of electrical sensors for monitoring vehicle wheel speed in antilock brake systems to detect an incipient wheel-skid situation. For instance, U.S. Patent No. 3,500,091 discloses a sensor which is mounted on the inner side of a vehicle wheel, and the sensor includes an annular electrical coil positioned adjacent both an annular magnet and a pole piece which are arranged concentrically with each other. While this sensor has certain advantages, it is subjected to dirt, slush and other foreign particles which may be splashed or thrown thereon from the roadbed.

U.S. Patent No. 3,473,120 discloses a sensor for a vehicle antilock brake system mounted in a wheel bearing lubrication chamber on the outer side of the vehicle wheel, and the sensor rotor is mounted on the hub cap assembly while the sensor stator is housed generally within the bore of a hollow axle. While this sensor has certain advantages, the mounting of its stator within the hollow axle serves to either appreciably reduce the number of stator teeth or the size thereof, to either limit the number of flux paths or reduce the size of the cumulative flux paths, to reduce the strength of the output signal of the sensor, or to make the stator-rotor gap more critical. U.S. Patent Nos. 2,798,976, 3,480,812 and 2,462,761 each show signal generating devices and illustrate

various arrangements of the rotor and stator thereof.

According to the invention, there is provided a sensor for generating an electrical signal indicative of the speed of a wheel rotating on an axle, the sensor being adapted to be connected to the axle by a nut threaded on the end of the axle, with a cap covering the sensor to enclose a chamber for holding lubricant, the sensor comprising a stator and a rotor which, when rotated relative to one another, are operative to create a magnetic field of varying flux density; the rotor being mounted within the cap; mounting means operative to secure the stator to the nut; and a coil disposed for sensing the variations in magnetic flux density created by the relative rotation of the rotor and the stator.

In the accompanying drawings:—

Figure 1 is a partial sectional view illustrating an electrical sensor according to the present invention;

Figure 2 is a developed view of a ferrous ladder for use in the rotor of the sensor of the present invention;

Figure 3 is an enlarged fragmentary view taken from Figure 1 and illustrating the means for mounting the ferrous ladder in the sensor rotor;

Figure 4 is an end elevation of the sensor stator partially broken away;

Figure 5 is an enlarged fragmentary view taken on line 5—5 of Figure 4;

Figure 6 is an enlarged fragmentary view taken on line 6—6 of Figure 4;

Figure 7 is an enlarged fragmentary view taken on line 7—7 of Figure 4; and

Figure 8 is a fragmentary end elevation of the sensor stator.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Referring now to the drawings in detail and in particular to Figure 1, there is shown generally at 1 an axle for a vehicle rotatably

mounting a vehicle wheel 3. A wheel bearing 5 is disposed between wheel 3 and axle 1, and a wheel bearing retaining nut 7 is threadably received on a free end portion 9 of the axle for retaining the bearing in place. A hub cap 11 is engaged with wheel 3 enclosing a lubricating chamber 13 which holds lubricant for the bearing 5. An electrical sensor 15, for generating an electrical signal to control actuation of a vehicle antilock brake system (not shown), is provided with a rotor 17 which constitutes hub cap 11 and associated component parts, as described hereinafter, and a stator 19 carried by the retaining nut 7 which also retains in place bearing 5, as previously mentioned.

More particularly, axle 1 is hollow, having an axially extending bore 21 which opens into the free end portion 9 of the axle, and a peripheral surface 23 of the axle free end portion 9 is threaded at 25. The anti-friction wheel bearing 5, of a type well known in the art, is rotatably positioned in engagement between axle peripheral surface 23 and a co-operating annular surface 27 on wheel hub 29. Bearing retaining nut 7 is threadably received on axle threads 25 and engaged with a spacer washer or shim 31 to maintain the bearing in place. The interfering engagement of a cotter key 33 between axle 1 and adjacent nut extensions 37 maintains the nut 7 in its assembled position on axle threads 25.

Hub cap 11, which is a type well known in the art and formed of either a non-ferrous metal or a plastics material, is generally cup-shaped having an annular side wall 39 integral with a base wall 41. A lubricant filler hole 43 is centrally provided in the base wall in which an insertable bayonet sealing plug 45 is received. Axially extending bore 47 is provided in hub cap side wall 39 as discussed hereinafter, and peripheral threads 49 are provided in the hub cap side wall 39 for threaded engagement with co-operating thread 51 provided in the leftward or open end of wheel hub 29. An O-ring type seal 53 is carried on hub cap side wall 39 in sealing engagement with wheel hub 29 to seal lubrication chamber 13.

Referring now to Figure 2, a ferrous ladder or track 57 stamped from substantially planar ferrous metal sheets is shown in its free form having opposite generally parallel side rails or strips 59, 61 with a plurality of predeterminedly spaced ribs or ties 63 integrally formed between the side strips and generally normal thereto. Ribs 63 are generally coplanar with side rails 59, 61 of ferrous ladder 57, and do not protrude. Ferrous ladder 57 is formed from strip material so that ribs 63 thereof do not protrude radially inwardly, as did the teeth of prior art rotors, thereby conserving space

or effecting the maximum utilization of the minimal space within the wheel bearing lubrication chamber 13. The ferrous ladder 57 is cut in predetermined lengths, shaped generally to an annular form with opposite ends thereof abutted to form a substantially continuous rotor piece or reluctance path for sensor 15, and ladder 57 is then positioned about bore 47 of hub cap 11. As shown in Figure 3, an annular slot or undercut 65 is provided in hub cap side wall 39 adjacent bore 47 in which one ferrous ladder side rail 59 is positioned, and a portion of hub cap side wall 39 is swagged or rolled at 67 over side rail 61 to maintain ferrous ladder 57 in its assembled position about bore 47 of hub cap side wall 39. When disposed in hub cap 11, the ferrous ladder 57 in its annular form has a thickness which is substantially constant throughout its axial expanse, i.e., side rails 59 and ribs 63 have substantially constant thicknesses. Of course, ferrous ladder 57 could also be retained in the hub cap bore 47 by other suitable positioning means, such as rivets, or by means of an epoxy resin or a glue, by providing a plastics case for the ferrous ladder which can be maintained in place in bore 47, or by providing a ladder which can be press-fitted in bore 47.

Referring now to Figures 1 and 4 to 8, sensor 15 is also provided with a stator assembly 71 having a generally annular support or mounting ring 73 of non-ferrous metal or other non-magnetic or a magnetic material, and ring 73 is provided with radially inner and outer circumferential or annular surfaces 75, 77 integrally formed between generally radially extending opposite sides 79, 81. The inner surface 75 is received on the peripheral surface 23 of axle 1 adjacent its free end 9, and a radially outwardly extending flange or retainer 83 is integrally formed and substantially coextensive with ring side 81, the ring side 81 and flange 83 being positioned in abutting engagement with extensions 37 of nut 7. Positioning or locating bosses 85 are integrally formed on outer annular surface 77 of ring 73 extending between sides 79, 81 thereof, and opposite locating edges or faces 87, 89 are provided on bosses 85 extending in imaginary planes which are generally normal to ring sides 79, 81 and surfaces 75, 77 extending through the centre of the ring 73. Although bosses 85 are generally keystone-shaped, other configurations are also contemplated. Bosses 85 are stepped to form a locating surface 91 substantially parallel to flange 83 and predeterminedly spaced from the ring side 79, and locating nipples or hubs 92 are integrally formed substantially normal to surfaces 91. Another locating edge or face 93 is defined on bosses 85 between locating surface 91 and ring side

79 and extending in an imaginary plane normal to the ring sides 79, 81 and extending through the centre of ring 73. Bores 97 are provided through bosses 85 and flange 83, and stator mounting means, such as studs 99, extend through bores 97 being threadably received in co-operating aligned threaded bores 101 provided in nut extensions 37 thereby to mount the ring 73 in fixed engagement with nut 7. In this manner, nut 7 not only retains bearing 5 in place but also carries or provides a mount for stator 71. Radially extending positioning or locating ribs or extensions 103, 105 are provided on the peripheral surfaces of bosses 85 for positioning or locating engagement with an annular or toroidal stator coil 107, as discussed hereinafter.

Stator 71 is provided with identical annular and generally planar pole pieces 109, 109a which are stamped from flat steel stock. Inner circumferential surfaces 111, 111a of pole pieces 109, 109a are sized to slidably engage ring outer surface 77, and a plurality of circumferentially spaced teeth 113, 113a are provided in the outer circumference of pole pieces 109, 109a, respectively. Keyway shaped slots 115, 115a are provided through pole pieces 109, 109a intersecting with inner surfaces 111, 111a, and the keyway slots are provided with opposed locating edges or slides 117, 119 and 117a, 119a. Axially extending locating holes 120, 120a are provided in pole pieces 109, 109a, and holes 120 in pole piece 109 are engageable with the ring nipples 92, as discussed hereinafter.

In the assembly of stator 71, pole piece 109a is positioned on ring 73 with its inner surface 111a received on ring surface 77 and with its keyway surfaces 117a, 119a in locating engagement with co-operating locating surfaces 87, 89 of ring locating bosses 85. Pole piece 109a is also engaged with ring flange 83 which not only serves to locate the pole piece but also retains or holds the pole piece on ring 73. Electrical annular coil 107 is provided with an inner circumferential surface 121 which is received in locating engagement on ribs 103, 105 of bosses 85, and outer circumferential surface 123 of coil 107 is positioned or terminates adjacent pole piece teeth 113, 113a. Opposite annular sides 125, 125a of coil 107 are adapted for engagement with pole pieces 109, 109a and a plurality of permanent magnets 127 are disposed in generally circumferentially extending spaces defined between bosses 85 and between coil inner surfaces 121 and ring outer surface 77, said magnets being in end-to-end relation and extending generally circumferentially about the stator 71. As is well known in the art, magnets 127 are disposed with all of their north and south

poles respectively adjacent to pole pieces 109, 109a to provide like polarity therein. Pole piece 109 is placed on ring 73 with pole piece locating edges 117 in locating engagement with locating face 93 of bosses 85, and the interior side of the pole piece is in locating engagement with stepped surfaces 91 of the bosses. As shown in Figure 7, holes 120 in pole piece 109 are received on ring nipples 92 when pole piece 109 is seated on locating surface 91, and nipples 92 are riveted over pole piece 109 to fixedly attach it to ring 73. It should be noted that the width of magnets 127 is slightly greater than the predetermined distance between ring flange 83 and stepped surfaces 91 so that pole pieces 109, 109a are mounted or pulled down into intimate contact with the magnets upon the assembly of the stator 71 thereby to provide a lower reluctance path and a greater output signal, as discussed hereinafter. To complete the description of the preferred embodiment, pole pieces 109, 109a are provided with grooves 135 in the outer peripheral edges thereof interrupting the continuity of teeth 113, 113a, and electrical leads 137 of coil 107 are led out of lubrication chamber 13 through bore 21 of hollow axle 1 for connection to the logic portion of an anti-lock brake system or the like (not shown). It should also be noted that the circumferential spacing and number of teeth 113, 113a in stator pole pieces 109, 109a correspond to the circumferential spacing and number of ribs 63 provided on ferrous ladder 57, and ferrous ladder 57 and hub cap 11 constitute rotor 17 for co-operation with the stator 71. From the foregoing it is apparent that the sensor 15 is mounted outboard of the vehicle wheel 3 and as close as possible thereto for monitoring wheel speed, and the mounting of stator 71 within the lubrication chamber 13 and on nut 7 effects maximum utilization of the minimal space, as does the use of hub cap 11 as a rotor component. The use of a plurality of magnets 127 provides a strong magnetic field, if the tolerance gap between rotor and stator 71 is small at one location and greater at another location, such gap variation is averaged due to the utilization of a plurality of individual flux paths which serve to minimize extraneous modulation.

With the component parts assembled as described hereinabove, it is apparent that magnets 127 are a means for providing a magnetic field, and operation of the vehicle effects rotation of wheel 3 on bearing 5 relative to axle 1 causing ribs 63 of ferrous ladder 57 to be continuously rotated into and out of radial alignment with stator pole piece teeth 113, 113a. Ferrous ladder ribs 63, stator teeth 113, 113a, pole pieces 109, 109a and coil 107 constitute means for providing a varying reluctance path, and when ferrous

ladder ribs 63 are radially aligned with the stator teeth 113, 113a, the gap therebetween is less than when the ferrous ladder ribs and corresponding stator teeth are radially misaligned. In this manner, rotation of hub cap 11 acts to continually vary the gap between ferrous ladder ribs 63 and stator teeth 113, 113a thereby effecting a low and high reluctance path for the magnetic field when the ferrous ladder ribs 63 are respectively in radial alignment and misalignment with the stator teeth. The continual varying of the gap between ferrous ladder ribs 63 and stator teeth 113, 113a in the magnetic field created by the magnets 127 serves to generate a varying electrical signal; and coil 107 and leads 137 constitute means for producing the electrical signal which is correlative of the wheel speed and transmitted to the logic portions of an anti-lock brake system (not shown).

#### WHAT WE CLAIM IS:—

1. A sensor for generating an electrical signal indicative of the speed of a wheel rotating on an axle, the sensor being adapted to be connected to the axle by a nut threaded on the end of the axle, with a cap covering the sensor to enclose a chamber for holding lubricant, the sensor comprising a stator and a rotor which, when rotated relative to one another, are operative to create a magnetic field of varying flux density; the rotor being mounted within the cap; mounting means operative to secure the stator to the nut; and a coil disposed for sensing the variations in magnetic flux density created by the relative rotation of the rotor and the stator.

2. A sensor according to claim 1, wherein the rotor and stator each have a plurality of members positioned around the circumference thereof and positioned with respect to one another to form, in use, a variable-reluctance path for the magnetic field.

3. A sensor according to claim 1, wherein the stator has a toothed portion and the rotor comprises an annular ferrous ladder with opposed side strips and a plurality of ribs spaced in relation to the toothed portion of the stator to form a variable-reluctance path for the magnetic field.

4. A sensor according to any preceding claim, wherein the coil is disposed in annular configuration about the stator.

5. A sensor according to any preceding claim, wherein the sensor is partially immersed in lubricant in the chamber.

6. A sensor according to any preceding claim, wherein the coil has at least one electrical lead passing from the chamber through the axle.

7. A sensor according to claim 1, wherein the stator includes at least one magnet extending at least partially about the stator.

8. A sensor according to claim 1, wherein the stator comprises a plurality of permanent magnets mounted in a ring substantially coaxial with the axle.

9. A sensor according to claim 1, wherein the rotor is mounted in a bore in a hub cap substantially coaxially with the axle.

10. A sensor according to claim 9, wherein the rotor comprises a pair of axially-spaced annular side rails disposed in the bore of the hub cap in displacement-preventing engagement therewith, and a plurality of ribs extending between the pair of side rails.

11. A sensor according to claim 10, wherein the stator includes a non-ferrous ring secured to the nut and extending about the axle, a pair of annular pole pieces being mounted on the non-ferrous ring and extending generally radially therefrom toward the rotor, a plurality of members being formed in the outer circumferential edges of each pole piece, the coil being disposed between the pole pieces adjacent to said stator members with at least one magnet disposed in intimate contact therewith between the pole pieces adjacent to the non-ferrous ring.

12. A sensor according to claim 11, wherein the pole pieces are identical.

13. A sensor according to claim 11 or 12, wherein the non-ferrous ring comprises a locating means operative to predetermine position the pair of pole pieces with respect to each other both circumferentially and axially.

14. A sensor according to claim 13, wherein the locating means includes at least one boss having opposite faces for locating engagement with the pole pieces.

15. A sensor according to claim 13, wherein the locating means includes a plurality of bosses, each boss having at least one face for locating engagement with the pole pieces.

16. A sensor according to claim 13, wherein the locating means includes at least one boss having a pair of opposite faces for locating engagement with one of the pole pieces, and a third face on said boss, the other of the pole pieces being positioned in locating engagement with the third face.

17. A sensor according to claim 16, wherein the third face is spaced between the pair of opposite faces.

18. A sensor according to claim 16, wherein the pair of opposite faces and the third face lie in imaginary planes which are substantially normal to the pole pieces.

19. A sensor according to claim 16, wherein the pair of opposite faces and the third face lie in imaginary planes which pass through the centre point of the non-ferrous ring.

20. A sensor according to claim 13, 130

- wherein the locating means includes mounting holes axially therethrough for receiving stator mounting means.
21. A sensor according to claim 16, wherein the boss comprises a mounting hole extending axially therethrough for receiving mounting means between the third face and one of the pair of opposite faces.
22. A sensor according to claim 13, wherein the non-ferrous ring comprises a radially-extending flange adjacent to one side thereof for holding one of the pole pieces on the non-ferrous ring.
23. A sensor according to claim 22, wherein the locating means includes at least one boss on the non-ferrous ring between the flange and the other side of the ring, a mounting hole extending axially through the flange and a boss for receiving stator mounting means, and opposite faces on the boss for locating engagement with the pole pieces.
24. A sensor according to claim 22, wherein the locating means comprises a plurality of bosses on the non-ferrous ring between the flange and the other side of the ring, and a surface on each of the bosses for locating engagement with the other pole piece, the surfaces being generally parallel to and predeterminately spaced from the flange.
25. A sensor according to claim 22, wherein the locating means includes at least one boss on the ring between the flange and the other side of the ring, a pair of opposite locating faces on the boss for locating engagement with the one pole piece, a third face on the boss between the pair of opposite faces, the other of the pole pieces being disposed in locating engagement with the third face, and a surface on the boss between the third face and one of the opposite faces generally parallel with the flange and predeterminately spaced from the other side of the ring for locating engagement with the other pole piece.
26. A sensor according to claim 24, wherein the other pole piece comprises a plurality of locating holes extending therethrough, with a nipple extending from each surface and being received in the locating holes, the free end of each nipple being riveted over into engagement with the other pole piece.
27. A sensor according to claim 23, wherein at least one rib is formed on the periphery of the or each boss, the coil being annularly disposed between the pole pieces, with the inner circumferential surface of the coil being in locating engagement with the or each rib.
28. A sensor according to claim 13, wherein each of the pole pieces comprise circumferentially-spaced teeth extending radially outwardly, the teeth being axially aligned with each other by the engagement of the locating means and the pole pieces, the teeth, pole pieces and magnets constituting a variable-reluctance path for the magnetic field.
29. A sensor according to claim 28, wherein the coil is disposed between the pole pieces and between the locating means and the pole piece teeth to sense the variations in magnetic flux density occurring during relative rotation of said rotor and said stator.
30. A sensor according to claim 11, wherein the opposite sides of the magnets are intimately engaged with the pole pieces.
31. A sensor according to claim 1, wherein a magnetic field is developed by the stator, and the rotor is operative to move through the magnetic field to vary the flux density thereof by providing a variable-reluctance path in cooperation with the stator.
32. A sensor, substantially as herein described, with reference to the accompanying drawings.

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**FIG. 8**